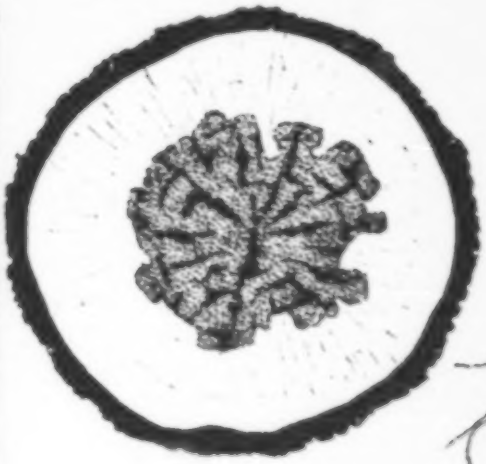
Pest Leaflet

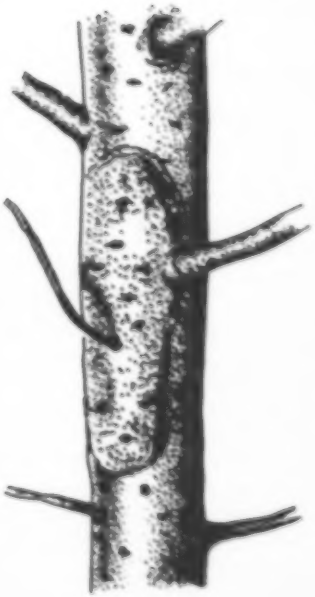
Government of Canada | Gouvernement du Canada
Canadian Forestry Service | Service canadien des forêts

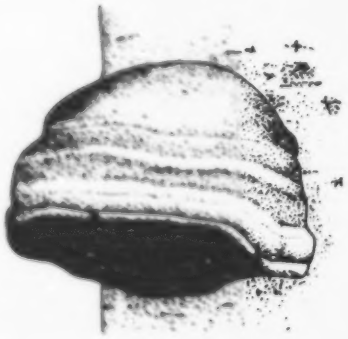
Pacific Forestry Centre | 506 West Burnside Road | Victoria, B.C.

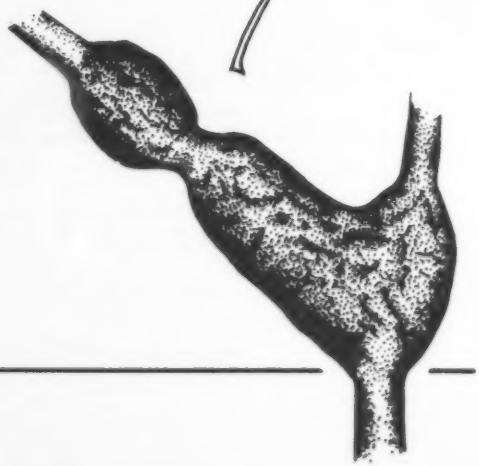
INTRODUCTION TO FOREST DISEASES

A. Funk









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Introduction

Present and future productivity of forest land is greatly affected by diseases, insects, fire, and adverse weather. Of these, diseases cause the greatest losses and present the greatest threat, outranking all other destructive agents. Many complex diseases threaten the forests and have created a demand for research in forest pathology and dissemination of this knowledge to all concerned with any aspect of forest productivity and reduction of losses. This leaflet presents basic information on causes and kinds of diseases with up-to-date annotations on principles of control and investigation.

The term "tree disease" covers a very wide range of injurious infections, abnormalities and disturbances of the normal structure and function of a tree. The causes of disease are likewise very numerous when one considers the many species of living organisms and the many non-living agents that affect tree health and growth. These agents of disease cause disorders that may culminate in the death of the tree, reduce growth, lower quality or predispose the tree to attack by other agents. By definition "tree disease" includes all injurious agents other than fire and insects or other animals.

The causes of tree disease are usually classified as Non-infectious or Infectious. This is a useful concept and helps to categorize disease agents, but very often disease results from a complex interaction of the tree with some factor of the environment (non-infectious) and a living, infectious agent such as a fungus. An appreciation of this interaction of living and non-living agents is often necessary to understanding disease outbreaks. However, some organisms considered as pests in epidemics brought on by adverse conditions can actually be beneficial by eliminating unthrifty individual trees or branches that are stressed, even in good circumstances.

In western Canada there are more than 300 native pathogenic fungi that are able to attack forest trees. For the most part, they occur only at low levels and live in dynamic balance with the forest trees. Forestry practice, however, involves the establishment of some artificial conditions and this may be done without regard to disease consequences. Examples from all the disease types are described here but many others exist, some of these are described in greater detail in the pest leaflets listed in the back. Leaflets dealing with insect damage are also available.

The technical terms used in this leaflet are in **boldface** and then defined in the glossary which follows the text.

Development of infectious diseases

The living organisms that incite disease are known as **pathogens**, and the affected tree is called the **host**. Most pathogens of western trees are **fungi** but several species of **dwarf mistletoes**, which are flowering plants, also cause serious diseases in trees.

Diseases affect the normal function of a tree in various ways. Needle casts may simply reduce the amount of food produced by photosynthesis. Stem cankers can weaken the bole or reduce transport of food to the roots. Root decay affects stability of the tree and also reduces water and mineral absorption.

The successful development of disease requires the following three factors:

1) *A susceptible host.* The host is unable to suppress pathogen development. Seasonal development and tree vigor also affect susceptibility of an inherently susceptible host.

2) *A virulent pathogen.* A pathogen must have the ability to cause disease and produce **inoculum** to infect the host, e.g., spores.

3) *A favorable environment.* Suitable conditions of moisture, temperature, etc. of sufficient duration to allow penetration of the host by the inoculum, and the subsequent establishment of the pathogen in host tissues are necessary.

The fungi causing tree diseases

Fungi are now accepted as a distinct kingdom of organisms that are neither plants nor animals. They live as **parasites** or **saprophytes** and obtain all their food from pre-synthesized sources. The basic vegetative structure is the microscopic **hypha**, a thread-like tube that may be separated into cells by the formation of cross-walls (**septa**). The **hyphae** together form a **mycelium** that can be visible as a whitish mat.

The spore-producing structures of the fungi are known as **fruit bodies** and are extremely diverse in shape and size, e.g., mushrooms, bracket fungi, discs, cups, flask-like **pycnidia**, or microscopic **conidiophores**. The fruit bodies are formed by the mycelium either following sexual fusion of nuclei, or simply vegetatively under the right conditions. The fruit bodies are the basis of classification of the fungi, with particular emphasis on the way the spores are borne. There are four main classes of fungi that produce diseases in forest trees and generally the type of disease is characteristic of the class of fungi, e.g., the basidiomycetes (bracket fungi, mushrooms) produce wood and root decay. There are exceptions, of course, and also overlaps, and these will be noted.

Mastigomycetes (Fig. 1)

The Mastigomycetes are microscopic soil and water molds that have a motile spore state. In forestry, they are usually associated with diseases of roots, especially of seedlings. Fruit bodies are never visible to the unaided eye. The motile, asexual spores are produced inside **sporangia**. The sexual spores are non-motile and termed oospores.

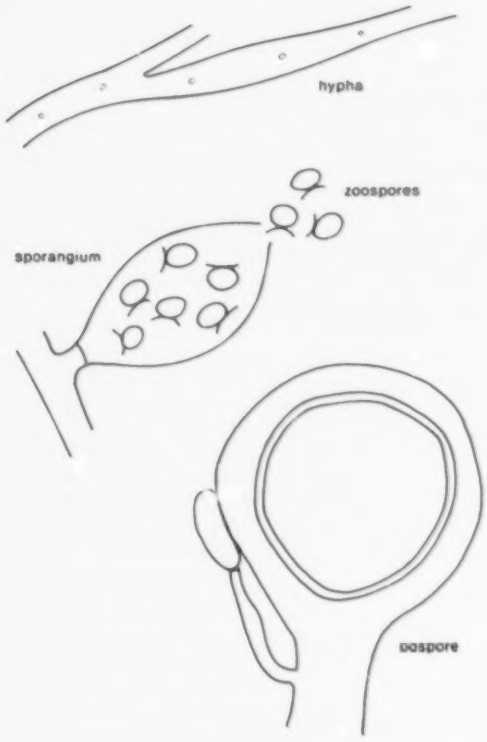

Fig. 1. Characteristics of the Mastigomycetes.

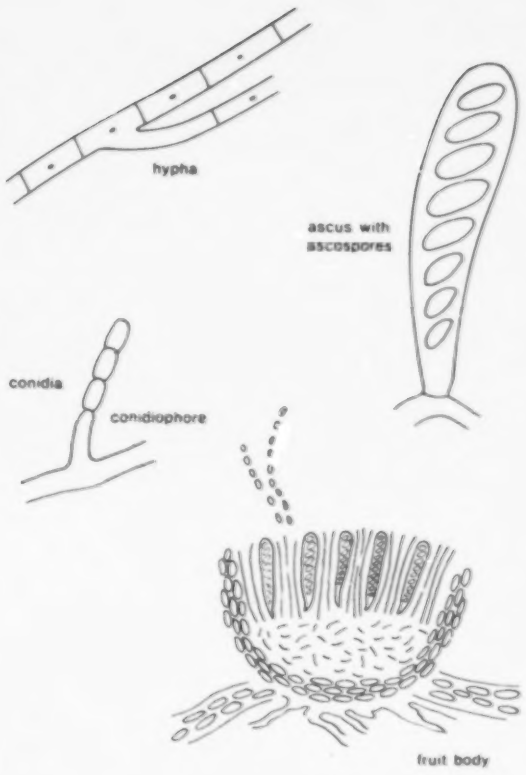

Fig. 2. Characteristics of the Ascomycetes/Deuteromycetes.

Ascomycetes/deuteromycetes (Figs. 2, 3)

The **ascomycetes** produce their spores in explosive sacs known as **asci**. The asci are produced in fruit bodies that are usually small (just visible to the unaided eye) but some are microscopic and some are large discs up to 15 cm diameter.

Many ascomycetes also produce an asexual spore stage that is known as the **anamorph**. Sometimes only the asexual stage occurs, but the relationship to the ascomycetes is obvious; these fungi are known collectively as the **Deuteromycetes**.

The diseases produced by this group of fungi are mostly the cankers, leaf blights and needle casts. Some notable exceptions will be pointed out in the following discussion.

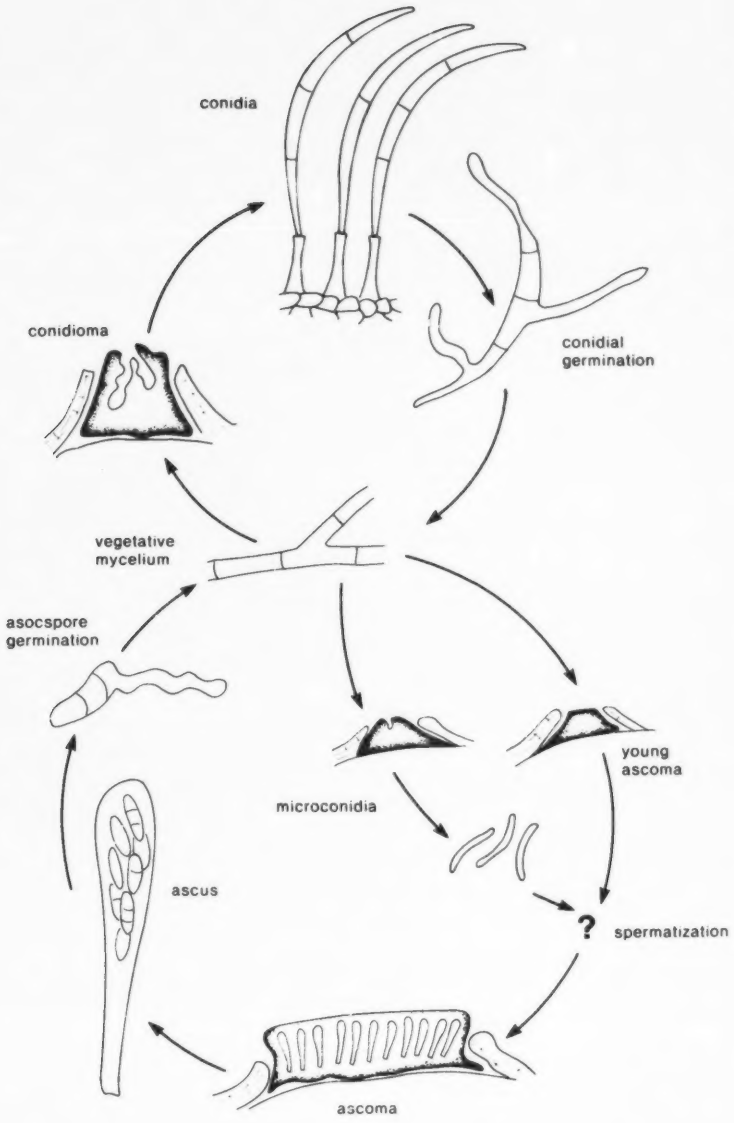

Fig. 3. Life cycle of an Ascomycete, *Dermea pseudotsugae*.

Basidiomycetes (Fig. 4)

The fruit body of the basidiomycete is the familiar mushroom, bracket fungus, or puffball, etc. The spores are borne on special cells known as basidia which occur on gills, in tubes, etc. of the fruit bodies. The diseases caused by this group of fungi are wood decays and root rots.

Some mushrooms, through their mycelium, form a beneficial association with the roots of forest trees whereby they assist in absorption of water and minerals for the tree. This is known as **mycorrhiza**.

Uredinales (rusts) (Figs. 5, 6)

The **Uredinales**, or rusts, form a unique group of **obligate parasites** that are classed as Heterobasidiomycetes. They produce up to five different spore states, one of which acts as a basidium.

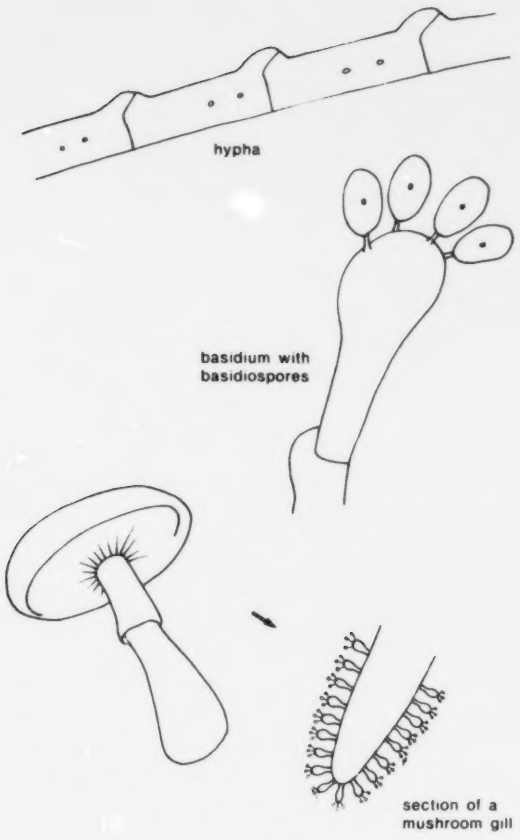

Fig. 4. Characteristics of the Basidiomycetes.

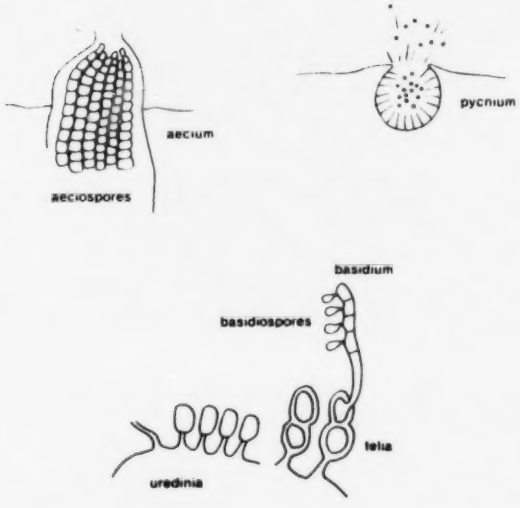

Fig. 5. Characteristics of the Uredinales (Rusts).

Many rust fungi complete their life cycle on two unrelated hosts. Because of these striking differences the Uredinales are considered separately from the basidiomycetes.

The name "rust" describes the characteristic sign of the pathogen where areas of the host are covered with conspicuous orange to yellow masses of loose spores. Some rusts produce blister-like cankers on stems, other attack only the needles, leaves or cones.

Diseases caused by mastigomycetes

Mastigomycetes cause damping-off of conifer seedlings and root rot of conifers. Damping-off of seedlings is often associated with *Pythium* under certain conditions of poor drainage. Certain conifers are susceptible to rotting of bark tissues of the roots by *Phytophthora*. The disease is usually severe under conditions of poor drainage.

Diseases caused by ascomycetes/ deuteromycetes

a) Leaf spots and Anthracnoses

The foliage of broadleaf trees is subject to a great variety of fungi that kill part or all of the leaf. Early defoliation results in some cases. The necrotic spots are sometimes sharply delineated and of a characteristic shape. Some diseases produce a black sclerotium in the leaf (tar-spot) that may fall away leaving a "shot-hole."

b) Needle casts and blights

Needle casts attack only young, developing needles of the current year, but **needle blights** attack any age of needles. There is usually little evidence of attack during the year of infection as the fungus grows vegetatively in the needle tissues. In the following year color changes occur and the fruit bodies may appear in the necrotic areas. Sometimes these changes are delayed a year or two. Frequently the needles are cast after spore discharge, but in some cases the dead foliage remains on the tree until it is weathered off.

Non-infectious diseases of needles, such as winter drying, late frosts, air pollution also produce discolored needles that are cast prematurely. These environmental diseases maybe distinguished by the absence of fruit bodies and lack of randomness seen in infectious needle diseases.

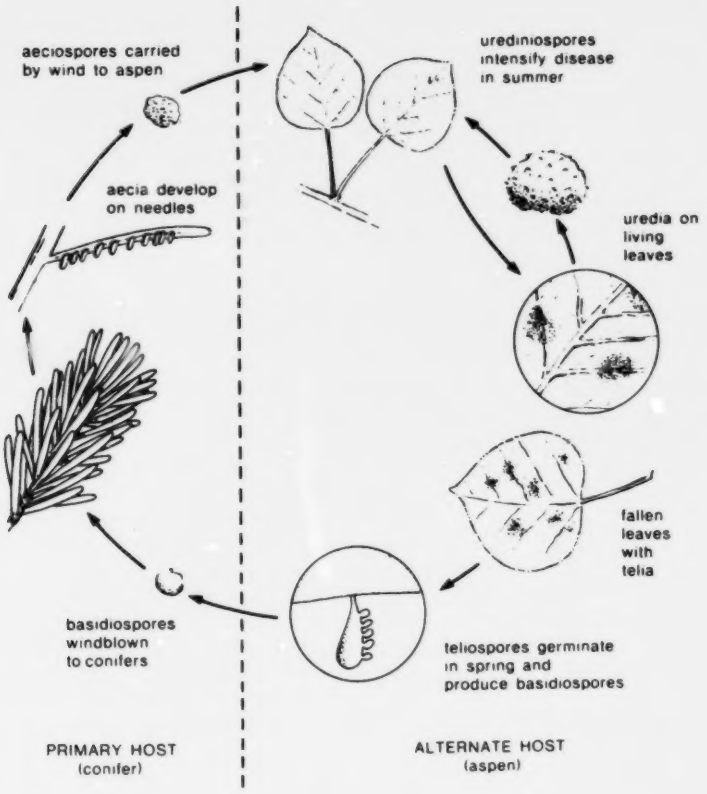
aeciospores carried by wind to aspen
aecia develop on needles
urediniospores intensify disease in summer
uredia on living leaves
fallen leaves with telia
basidiospores windblown to conifers
teliospores germinate in spring and produce basidiospores
PRIMARY HOST (conifer)
ALTERNATE HOST (aspen)

Fig. 6. Life Cycle of a Rust, *Melampsora medusae*.

c) Cone, seed and seedling diseases

Several diseases infect the fruit of a tree and then kill the seed or the seedling that emerges at germination.

Sirococcus infects the cones and produces slimy conidia that stick on the seeds. The fungus does not kill the seed, but may attack the germinant when it emerges (seed-borne disease).

Caloscypha infects cones that fall to the ground. This fungus penetrates the seed coat and destroys the seed.

d) Cankers and diebacks (bark diseases)

A canker is a localized lesion or area of necrosis in the bark of stem or branches. Three types of cankers are recognized: i) **Perennial** or **Target** cankers are roughly circular and may contain much callus at the face or margins. The fungus is slow growing, roughly equaling radial growth of the tree. ii) **Annual** or **Canker Blight** are cankers that develop rapidly for one season only and contain little or no callus. They frequently occur on stressed trees and disappear in the absence of the stress factors. iii) **Diffuse cankers** grow more rapidly than the radial growth of the tree and so contain little or no callus. They usually girdle the tree after several years.

If the canker fungus also invades the underlying wood, **canker rot** is produced.

Atropellis canker of lodgepole pine is a perennial canker caused by the ascomycete *Atropellis piniphila*. It is characterized by large, sunken, resin-soaked cankers and a bluish-black stain of the wood. Black disc-like fruiting bodies 2-3 mm in diameter are usually present.

Annual cankers of Douglas-fir are caused by the fungus *Diaporthe lokoyae* (anamorph = *Phomopsis lokoyae*) in times of water stress or frost

damage. The killed bark is callused out in the following growing season and complete healing can result.

e) Root rots

Nursery — Species of *Fusarium*, *Phoma* and *Cylindrocladium* are associated with damping-off and dieback of seedlings. These fungi are Deuteromycetes, the anamorphs of ascomycetes.

Young Growth — *Rhizina* is an ascomycete which attacks young trees especially in areas of recent fires. It produces a very large fruit body

Mature Tree — Blackstain root disease of older trees is caused by the ascomycete *Ceratocystis wageneri*.

Diseases caused by basidiomycetes

a) Wood stains

Certain deep-seated stains represent the incipient stage of decay but others are caused by ascomycetes (q.v.) that do not break down the wood appreciably.

b) Wood decay of stems

Stem decays are classified as heart rots or sap rots on the basis of the type of wood attacked. In living trees most decay fungi are in the heartwood; some may attack both heartwood and sapwood; a few attack only sapwood.

Decays are further classified on the basis of the type of rot produced. In general, the fungus breaks down the bond between the lignin and cellulose components of wood and utilizes either or both in its growth. Fungi that utilize only cellulose cause **Brown Cubical Rots** because the decayed wood is brown and forms into cubes. Those fungi that utilize both lignin and cellulose cause white rots, because the decayed wood is light in color and never cubical. White rots may be stringy, laminated, pitted or mottled depending on the species of fungus involved.

Decay fungi gain access to the heartwood or sapwood through broken branches and tops, scars and roots. Infection can occur by airborne spores or by spread of mycelium from a previously infected tree, as in root contact or **rhizomorphs** spreading in the soil.

Decay fungi normally develop slowly and rot may be present in a tree for many years before the spore producing conks or mushrooms appear. The presence of sporophores is often a sign of advanced decay in the tree. As long as the conditions for growth are favorable the process of decay is continuous; requirements are favorable temperature, adequate moisture, oxygen and suitable wood substrate.

c) Root rot and stump infections

Certain basidiomycetes, such as *Phellinus weirii*, colonize large roots of mature trees and decay the wood and bark. The fungus spreads to other trees by root contact and establishes a rot center in the stand. Affected trees are subject deteriorating crowns and windthrow. Even after cutting, the fungus remains alive in the dead roots and may perpetuate the disease to future rotations.

Certain root rot fungi, e.g., *Heterobasidion* (*Fomes*) *annosum*, can colonize the freshly cut stumps of healthy trees and establish themselves in the dead roots. For this reason stump treatments are used during commercial thinning to stop pathogenic fungi and encourage normal saprophytic decay fungi.

d) Wood decay of dead timber and slash

Removal of slash and wood debris in a forest is not considered a disease, but rather an important process in sanitation and return of elements to the soil. It is a complex process that involves not only basidiomycetes but also wood-boring insects and bacteria in a succession.

Some tree species are more resistant to decay than others (e.g., western red cedar is more durable than Douglas-fir) and exposed sapwood is less resistant than heartwood. Moisture is a critical factor; approximately 25% water content or more is required for decay to proceed.

Diseases caused by uredinales (rusts)

The rusts are obligate parasites that often have a complex life cycle that may require two unrelated hosts to complete. Two spore states (pycnial and aecial) occur on the primary host and three spore states (uredinial, telial and basidial) occur on the alternate host. A **host-alternating** rust is termed **heteroecious**. Some rusts have fewer spore states and complete their life cycle on a single host;

these are termed **autoecious**. The primary host of heteroecious rusts is usually a conifer, but there are exceptions.

a) Leaf and needle rusts (e.g. *Melampsora, Gymnosporangium)*

Most foliage rusts are **host-alternating**. Because the primary host is most frequently a conifer, the **pycnial state** and **aecial states** are both found on needles. Pycnia appear in spring as inconspicuous spots that exude pycniospores in droplets of sweet liquid. Aecia form soon after at the same site and are conspicuous white, yellow or orange structures with masses of aeciospores. **Aeciospores** infect the non-coniferous **alternate** host.

On the broadleaved **alternate host**, e.g., poplar, uredinia develop as orange-reddish pustules that produce several crops of urediniospores which intensify infections on the same broadleaf host. Telia develop in late summer and the teliospores can germinate the same summer or overwinter. On germination the teliospore produces a basidium which in turn produces four basidiospores. The basidiospores infect only the coniferous primary host.

Leaf and needle rusts are most important on young trees because the premature defoliation that results may weaken the tree in the crucial stage of growth.

b) Cone rusts *(Chrysomyxa)*

Spruce cone rusts are economically important diseases in British Columbia. **Aecia** are produced on the cone scales and the whole cone may be destroyed including the seeds, or germination only may be reduced. **Resinosis** can hinder dispersal or extraction of seeds from the cones.

Alternate hosts of the cone rust are inconspicuous flowering plants *(Moneses, Pyrola)*.

c) Stem rusts *(Cronartium)*

Stem rusts are among the most destructive pathogens and occur only on pines. They produce large blister-like cankers or galls that usually weaken the tree or branch and eventually result in mortality.

White pine blister rust is the best known disease in the stem rusts. It has essentially eliminated white pine as a usable species. Its **alternate host** is currants and gooseberries *(Ribes)*. The large, orange, aecial blisters that appear in the spring shower countless aeciospores into the wind infecting the leaves of **alternate hosts**. This is not a native **pathogen** but was introduced around 1910 on imported pines from Europe.

d) Broom rusts *(Chrysomyxa, Melampsorella)*

Conspicuous, yellowish-orange **witches brooms** are produced in spruce trees by the **fungus** *Chrysomyxa arctostaphyli*. This is the aecial stage fruiting in the current years' needles which are shed in the fall. Because the rust is a **systemic infection** new needles are infected each year. This disease causes dead branches, bole deformation and increment loss. The **alternate host** is the common bearberry *(Arctostaphylos uva-ursi)*.

Melampsorella caryophyllacearum causes brooms of the true firs (*Abies* spp.). The **alternate host** is chickweed.

Viruses, bacteria and mycoplasmas

These three groups of submicroscopic to microscopic organisms are important in plant and tree diseases in many parts of the world. However, in western Canada none of these is known to be involved in a major tree disease. A rare gall disease on stems of Douglas-fir is caused by bacteria.

The mycoplasmas are related to the bacteria but they produce symptoms similar to those produced by viruses, i.e., "yellows." Certain undiagnosed minor diseases of western trees may be caused by these organisms.

Disease caused by dwarf mistletoes

(Fig. 7)

Dwarf mistletoes *(Arceuthobium)* are parasitic plants that cause severe swelling, brooming and deformation of host trees. The germinating seed produces a root capable of penetrating the bark and which ramifies in the phloem. Later, parts of this endophytic system become embedded in successive layers of wood. Infections are perennial and after 2 to 5 years they produce conspicuous male and female shoots. The seeds, produced by the aerial female shoots, are sticky and forcibly ejected to distances of 7 to 10 metres.

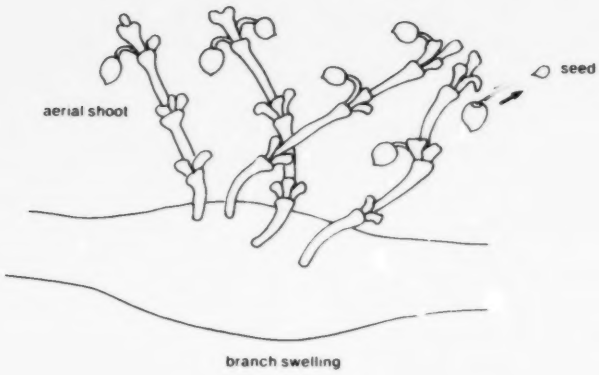

Fig. 7. Dwarf mistletoe aerial shoots in branch swelling and explosive fruit releasing seed.

Non-infectious agents of disease

Non-living stress factors are able to cause injury and death to trees. They are mostly meteorological stresses such as temperature and moisture, but many man-made environmental causes such as air pollution also contribute to this class of diseases. As a rule, non-infectious diseases have uniform *symptoms* on the entire tree while symptoms of infectious diseases are variable and more random. Non-infectious diseases frequently affect all species in an area with similar symptoms, or, if only one species is affected, then all trees of that species in the area will be similarly affected. The general decline of forest vigor in many parts of the world is now attributed to "acid rain," the deposition of SO_2 and other pollutants from industrial air pollution.

Direct fume damage to foliage may also occur in the vicinity of smelters and pulp mills. The symptoms are yellowing and withering of the leaves and if repeated year after year, this will lead to dieback of branches.

Frost and cold weather are serious causes of damage to trees in Canada. Winter cold, and frosts of spring and autumn, affect trees differently. Thus, a late spring frost may kill the newly-flushed shoots and leaves, whereas an early autumn frost may cause damage to bark that has not hardened for the winter.

"Red belt" or winter drying is a climatological cause of needle discoloration that affects large tracts of coniferous forests. The affected areas are often in the form of narrow, horizontal "belts" on a mountainside. Tree mortality has resulted from these occurrences that are associated with warm winds in winter. It was sometimes explained as increased transpiration when the ground was frozen resulting in desiccated needles, but it is now believed to be caused by a rapid drop in temperature following a thaw.

Sunscald is heat injury to bark and **cambium** resulting from exposure of young trees to intense sunlight. **Cankers** and open wounds may occur where the bark is killed.

Principles of control of forest diseases

Many diseases exist in the forest for which no control measures have been devised or for which control is not feasible on a large scale. The following principles are used successfully for general and specific control of diseases that are amenable to treatment.

1. Proper site selection

   Correct site selection for planting will eliminate most native diseases in a stand by promoting good growth and natural resistance.

2. Forest management

   Practices such as thinning, pruning, and cutting can be used to control certain diseases. Dwarf mistletoe control, for example, is almost entirely dependent on harvesting methods.

3. Direct control

   Infection can be prevented and residual disease foci can be eliminated by measures such as application of fungicides, stump treatment after felling, and removal of diseased stumps.

4. Quarantine

   The legal restriction of movement of trees from a disease area to disease-free areas is a means of controlling spread or exclusion of a pest.

5. Breeding for Resistance

   Selection of trees that show resistance to disease and their use in breeding programs offers hope that some pest problems may be overcome.

Principles of forest disease investigations

The elucidation of forest disease syndromes often involves much painstaking study. The presence of deceptive factors in the environment, such as secondary fungi and fungal variability, require that each step of an investigation be rigorously regimented according to scientific principles. The following facets of a pathogen are important to forest pathology reasearch:

1. Culturing — the suspected pathogen should be obtained in pure, artificial culture, where possible.

2. Pathogenicity study — by using Kochs' Postulates (see below), the organism should be proven to be the cause of the disease.

3. Life cycle — all spore states should be elucidated and related to host range and phenology.

4. Conditions for infection — general physiology and requirements for spore germination, penetration, etc.

Rules of Proof (Koch's Postulates)

To prove that an organism is the cause of disease:

1) show constant association with the disease
2) isolate the organism in culture from the disease
3) inoculate healthy plant with the culture and produce the same disease
4) re-isolate the same organism from inoculated plants

Submitting disease samples

Reporting disease is a valuable service in helping to protect the forests. This is best accomplished by sending a sample of the disease along with a written statement of observations and data to:

Forest Insect and Disease Survey,
Pacific Forestry Centre,
506 West Burnside Road,
Victoria, B.C. V8Z 1M5

Special sampling forms (collection slips) are available from the above address, but if these are not used the following information should be included:

1. Date and location of collection
2. Species and condition of the tree
3. Name and address of the collector
4. Observations and pertinent comments

The disease sample should be adequate to show symptoms well and allow for culturing if necessary. Include any fungus fruit bodies that are present, e.g., Conks or mushrooms.

Samples should be wrapped in paper in a protective container, not in plastic bags which encourage mold growth and deterioration. Diseased foliage should be pressed and dried before being sent in. Samples to be used for culturing should be placed in plastic bags if there is a danger of them drying out.

Specialists at the research centre are able to diagnose the disease from symptoms, fruit bodies and cultures.

Additional information

Forest pest leaflets that give a more detailed description of the forest diseases are available from this centre.

Diseases affecting seedlings

Joint Report No. 12. Diseases and Insect Pests in B.C. Forest Nurseries.
FPL. No. 61. Fusarium root rot of Douglas-fir nursery seedlings.

Diseases affecting foliage

Leaf and needle rusts

41. Needle rust of lodgepole pine.
45. Needle rusts of true firs in British Columbia.
42. Shoot blight of poplars.
48. Broom rusts of conifers in British Columbia.
49. Melampsora foliage rusts in British Columbia.

Needle casts and blights

27. Elytroderma disease of pines.
32. Rhabdocline needle cast of Douglas-fir in British Columbia.
39. Common needle diseases of spruce in British Columbia.
43. Pine needle casts and blights in British Columbia.
46. True fir needle blights in British Columbia.
52. Lophodermium needle cast of pine in nurseries and plantations.
71. Foliage diseases of western larch.

Diseases affecting fruit

50. Spruce cone rusts in British Columbia.
BC-X-231. A guide to common insect pests and diseases in spruce seed orchard.

Diseases affecting bark

25. Atropellis canker of lodgepole pine in British Columbia.
26. White pine blister rust in British Columbia.
37. Stem rusts of pine in western Canada.
60. Diaporthe canker of Douglas-fir in British Columbia.
65. Cankers of spruce in British Columbia.
42. Shoot blight of poplars in British Columbia.
63. Common pests of Arbutus.

Diseases affecting roots

FR-12. *Phellinus (Poria) weirii* root rot. Detection and management.
3. Poria root rot in Douglas-fir in British Columbia.
15. Annosus root rot in Douglas-fir and western hemlock in British Columbia.
56. Rhizina root rot of conifers.
67. Blackstain root disease in B.C.
BC-X-203. Armillaria Root disease. A guide to disease diagnosis, development and management.

Wood decay

55. True heartrots of B.C.
62. Wound parasites causing tree decay.

Diseases caused by dwarf mistletoes

BC-X-72. Dwarf mistletoes in British Columbia. Recommendations for control.

Copies of published disease Pest Leaflets may be obtained from:

Information Office
Pacific Forestry Centre
506 West Burnside Road
Victoria, B.C.
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Glossary of forest disease terms

Aecial state: the second spore stage in the life cycle of rust fungi producing aeciospores

Aeciospore: rust spore formed in an aecium

Aecium, pl. **Aecia**: a cup-like structure which produces chains of aeciospores

Aerial shoot: stem-like portion of dwarf mistletoe plant outside the host bark. Its primary function is reproduction

Alternate host: the host that bears the uredinia and telial stages of a host-alternating rust

Anamorph: the asexual spore state of a fungus

Annual: growth continuing for one season only

Apothecium, pl. **Apothecia**: cup-like structure of Ascomycetes containing asci

Ascomycetes: a group of fungi typified by the ascus within which are produced the ascospores — typically eight (the sac fungi)

Ascospore: spore produced in an ascus

Ascus: pl. **Asci**: sac-like structure containing a definite number of ascospores, usually eight

Asexual reproduction: reproduction not involving nuclear fusion

Asexual state: see anamorph

Autoecious: rusts completing the life cycle on one host (cf. heteroecious)

Bacterium, pl. **Bacteria**: typically one-celled microorganisms which have no chlorophyll but have cell walls, and multiply by simple division

Basidiomycetes: a group of fungi characterized by the definite number of basidiospores — typically four — produced on the surface of a basidium (jelly fungi, mushrooms, puffballs and stinkhorns)

Biological control: the control of a pest by pathogens, insects or rodents

Blight: sudden drying and browning involving whole organs such as: fruits, blossoms, leaves, twigs and shoots

Blue sapwood stain: a deep-seated blue, black, or gray discoloration confined mostly to sapwood

Brown cubical rot: a rot in which the causal fungi generally made a more concentrated attack on cellulose than lignin. The brown friable residue splits along rectangular planes in the advanced stage of decay

Callus: tissue that develops at the margins of wounds or cankers

Cambium: the actively dividing layer of cells which lies between xylem and phloem tissues

Canker: an area of diseased tissue, often sunken, on a living stem or branch

Canker blight: cankers that develop for one season only

Canker rot: cankers that invade underlying wood

Chlorosis: yellowing of normally green tissue owing to subnormal chlorophyll content

Conidiophore: a specialized hypha which bears conidia

Conidium, pl. **Conidia**: an asexual spore formed usually on a specialized hypha (conidiophore) or in a pycnidium

Damping-off: disease of seedlings by a group of fungi, affecting roots and stem

Decay: the process by which sound wood is destroyed by the action of fungi

Deuteromycetes: the anamorphic fungi, an artificial grouping of conidial states of Ascomycetes and n few Basidiomycetes whose teleomorphs have not been found or are lacking

Diffuse cankers: cankers containing little or no callus

Dioecious: unisexual, the male and female elements in different individuals.

Dwarf Mistletoes: parasitic flowering plants

Fruit body: a fungus structure specialized for producing spores: e.g., conk, mushroom, apothecium

Fungus, pl. Fungi: parasitic or saprophytic organisms made of cellular filaments known as hyphae, reproducing with formation of spores.

Heart rot: decay characteristically confined to the heartwood

Heartwood: the inner layers of wood which, in the growing tree, contain only a few living cells

Heteroecious (of rusts): requiring two unrelated host plants to complete their life cycle (cf. autoecious)

Host: a living organism harboring a parasite

Host-alternating: changing of host species, essential for the completion of the life cycle of a heteroecious rust

Hymenium: the spore-bearing layer of a fungus fruit body

Hyperparasite: an organism that is parasitic on another parasite

Hypertrophic symptoms: symptoms resulting from excessive growth.

Hypha, pl. **Hyphae**: a fungus filament of the vegetative body of a fungus, cf. mycelium.

Hypodermataceae: a group of Ascomycetes, some cause needle cast in conifers.

Immunity: having qualities which do not permit infection.

Imperfect state: see anamorph (syn. asexual state).

Infection court: the place on the host where a pathogen initiates infection.

Inoculum: infectious material of a pathogen.

Lesion: an area of diseased tissue.

Mycelium, pl. **Mycelia**: a mass of fungus hyphae.

Mycelial fan: a typically fan-like mass of hyphae as in Armillaria root rot.

Mycoplasma: similar to bacteria but smaller and lacking cellwalls; often causing virus-like symptoms.

Mycorrhiza: an association of a fungus with root of a tree

Necrosis: death of cells or tissues

Necrotic symptoms: symptoms produced by the death of plant cells

Needle blight: fungal attack on needles of any age

Needle cast: a disease resulting in premature dropping of the needles in coniferous trees, frequently associated with attack by certain fungi, but also caused by non-infectious diseases, usually on needles of current year

Obligate parasite: an organism that lives only on living host tissue

Parasite: an organism living on another living organism and obtaining its food from it

Pathogen: a living organism that incites disease

Perennial: growth continuing from year to year

Perfect state: see **teleomorph**

Periderm: protective layer of bark

Perithecium, pl. **Perithecia**: flask-like fruit body of ascomycetes

Phenology: the science of the relations between climate (seasons) and biological phenomena such as bud break, flowering, etc.

Phellogen: cork cambium giving rise to the outer bark or periderm

Phloem: inner bark tissue which functions in the transport of foods from the leaves

Photosynthesis: the building up in green plants of plant foods from carbon dioxide and water. The energy for this process is obtained from sunlight acting on chlorophyll.

Primary host: the host on which the pycnial and aecial states of rusts develop

Pycnial state: state in the life cycle of rusts in which pycniospores are produced

Pycnidium pl. **Pycnidia**: a flask-like body, lined inside with conidiophores, and producing asexual conidia (spores)

Red heartwood stain: a pronounced reddish coloration, induced by fungi in the heartwood of conifers

Resinosis: an abnormal flow of resin or pitch from conifers

Resistance: ability to suppress or retard the activity of a pathogen

Rhizomorph: a thread or cord-like structure made up of hyphae

Saprophyte: an organism using dead organic material as food and commonly causing its decay

Sap rot: a rot occurring in sapwood

Sapwood: the outer portion of a woody stem, i.e., the functional xylem

Sclerotium, pl. **Sclerotia**: a hard mass of fungus tissue, resistant to unfavorable conditions

Secondary fungus: a weak parasite or saprophyte which usually infects only predisposed, weakened, or killed individuals

Secondary host: the host on which the uredinial, telial and basidial states of rusts develop

Secondary inoculum: inoculum produced during the growing season (contrast with primary inoculum)

Septum, pl. **Septa**: the cross wall in a hypha

Sexual reproduction: reproduction involving the union of two nuclei.

Sexual state: see **teleomorph**

Sign: visible portion of a pathogen on a diseased host, e.g., spores, mycelia, fruit body

Sporangium, pl. **Sporangia**: an organ in which are produced asexual spores, especially Mastigomycetes

Spore: a small fungus structure functioning as a seed, but differing from a seed in that a spore does not contain an embryo

Symptom: any reaction of a host to disease

Systemic infection: a pathogen capable of spreading through its host, e.g., one kind of dwarf mistletoe infection in which the "root" system is in the terminal bud and keeps pace with the growth of the host branch

Target: in concentric rings

Teleomorph: the sexually produced spore state of a fungus

Teliospore: the rust spore giving rise to basidiospores

Vegetative state (of a fungus): a growing or food absorbing state; the mycelium; distinguished from reproductive state, in which spores are produced.

Witches' broom: excessive branching parts of trees as the result of disease (rusts, dwarf mistletoes) or physiological disorder

Xylem: wood; principal strengthening and water-conducting tissue of the stems, roots and leaves of plants